Four-Dimensional Sustainable E-Services

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Four-Dimensional Sustainable E-Services

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Abstract

E-services are not sustainable, unless specifically designed for sustainability along four dimensions (4D): economical, technical, environmental, and social. Designing 4D-sustainable e-services is very complex, mainly due to the many challenges in communicating and assessing sustainability. This paper proposes a conceptual model that identifies the core elements of 4D-sustainable e-services. Our goal is to enhance the shared understanding amongst sustainability stakeholders, while easing sustainability assessment and negotiation. We illustrate the value of the conceptual model using a real-life case study featuring an airport baggage handling system[2].

1. Introduction

We live in a society that increasingly depends on e-services—*services* that are provisioned via IT technologies, and involving multiple parties that exchange something of value. Examples are Internet banking, disaster management, and electronic health record. As e-services become more integral to the life of people, enterprises, and governments, it becomes more critical that they last, i.e. that they are *sustainable*. We need e-services that are economically, technically, environmentally, and socially sustainable: *economic sustainability* to ensure that e-services create economic value; *technical sustainability* so that their technical assets actually enable the e-services to cope with changes; *environmental sustainability* to avoid that e-services harm the environment they operate in; *social sustainability* to ensure e-services provide fair exchange of information between parties. From now on, we call such e-services, four-dimensional sustainable, in short, "4D-sustainable".

Consider for example the *baggage handling* e-service in airports. Provided services center around transporting the travelers' baggage. To provide this e-service a group of parties (traveler, airline, airport, baggage handlers) work together and exchange something of value ("money", "services for baggage transportation", "right to check security"). From economic perspective, the baggage handling e-services can only be sustainable if each party can gain profit. From a technical perspective, the e-service is sustainable if the IT technology behind it can deal with changes (e.g., changes in security regulations). From environmental perspective, the e-service is sustainable when it minimizes its environmental impact, for example in terms of energy consumption (e.g., through energy efficient baggage routing). Finally, from the social perspective, the e-service is sustainable if it ensures that all actors are treated fairly in terms of their rights (e.g., protecting sensible information about baggage location).

Despite their integral role in the society, current e-services are not designed for sustainability. To create sustainable e-services, it is best to design for sustainability upfront. This paper aims at taking the first step towards such a design. E-services will not be sustainable, unless we specifically design them to be; however, designing 4D-sustainable e-services is vastly complex [1]. So far, service engineering research has left dealing with such complexity unassisted—which can be attributed to the many initial technical challenges that needed to be overcome.

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Our goal is to fill this gap: we propose a conceptual model for representing 4D-sustainability. Our conceptual model takes a value modeling perspective to sustainability of e-services, where the e-service is viewed as a set of value exchanges between actors (for example, the baggage handling service). We attribute the sustainability of an e-service to a positive value exchange between actors. Our goal is to enhance the common understanding amongst stakeholders, but also to allow for assessments and negotiation. The conceptual model has clearly defined modeling constructs to design and to reach common understanding about the sustainability of the e-services.

2. Related Work

The concept of sustainability derives from the report of the Brundtland commission [2] where the expression “sustainable development” was coined as “the kind of development that meets the needs of the present without compromising the ability of future generations to meet their own needs”. Although current literature emphasizes the need of a multi-dimensional approach on sustainability, existing research focuses on the individual dimensions; the social dimension [3], the environmental dimension [4], economic dimension [5], or the technical dimension [6]. To date, little research [7] has been performed to further develop a multi-dimensional approach. A recent example is the work in [8] where the authors define sustainability as a software quality attribute categorized in four dimensions.

3. Running Example

Our running example is extracted from a baggage handling system. A SOA solution provider company has designed a service inventory for a baggage handling system that is adoptable in different types of airports (e.g. hub, domestic, international, low-cost) and can be used by different types of airlines (e.g. legacy, domestic, international and intercontinental). From a bird's-eye view, baggage handling is quite simple. The traveler arrives at check-in desk, and her/his baggage is tagged by the Airline. Airport plans and governs the baggage handling process. Ground handlers do the real baggage management. They can optimize the routes taken by the carts to get the most urgently needed bags to their destinations faster. They also track-and-trace the baggage. Finally, the security provider supports the screening of the baggage. Consequently, baggage handling relies on five different actors: traveler, airline, airport, ground handlers, and security provider.

4. 4D-Sustainability Conceptual Model

To represent 4D-sustainability, we propose a conceptual model embracing the fundamental elements that represent the 4D-sustainable e-services. To do so, we carried out a literature review on 4D-sustainability followed by focus groups [9], putting together our expertise in services engineering and (at least) one of the sustainability dimensions. As a result we: (a) defined what a 4D-Sustainable e-Service entails; (b) created the 4D-Sustainable Conceptual Model. Finally, we discussed the model with the aid of a real-world case study in the area of baggage handling systems.

The conceptual model is fully approached from the value proposition point of view; in all of these dimensions, we identify a concept of value, i.e. something that expresses the degree of utility, or benefit, created by a service in a specific dimension. Subsequently, we define each of the four sustainability dimensions as positive value exchange specifically for that dimension.

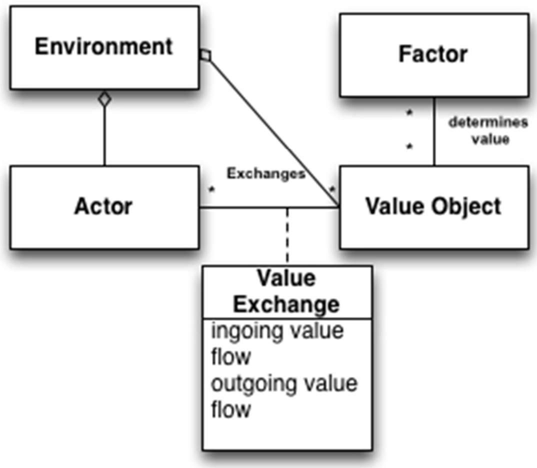

Figure 1: The 4D-Sustainability Conceptual Model

The 4D-Sustainable Conceptual Model, shown in Figure 1, entails interrelated core elements that are prevalent in all the four sustainability dimensions. These core elements are instantiated for each of the sustainability dimensions.

4.1. Core Elements

In this section we present the each of the core elements shown in Figure 1.

Environment. Environment is the context that entails actors and a *finite* amount of resources and is constrained by a set of rules (e.g., of physics, society, economy).

Actor. An actor is an entity that has the goal of achieving a positive net value by exchanging value objects.

Value Object. A value object is a resource that has economic, technical, social, and/or environmental value. For instance, from economic perspective, a value object is a service, product or even an experience that has economic value. The important point here is that a value object is *of value* for one or more actors.

Value Exchange. A value exchange is the exchange of value objects between actors. The net value of the exchange is the difference in value of the exchanged objects.

Factor. A factor is a property of the environment that determines or influences the value of a value object. Factors are *drivers of change:* they are the only possible element that triggers unforeseen changes in the environment.

4.2. Variations for the sustainability dimensions

Between the four dimensions, the notion of sustainability varies significantly, therefore the core elements have very different semantics. In this section, we apply the 4D-Sustainable conceptual model to each dimension: we first define the concept of sustainability with respect to the specific dimension, and then we represent the specific semantics of the core elements.

4.2.1. Economic Sustainability

Economic sustainability is about creating **a positive economic value exchange** between all the actors participating in the e-service. In the economic dimension, all actors are legal entities that are profit-and-loss responsible. Such actor exchange a service, experience, money or in general anything of economic value. To be sustainable, all these actors should make *profit*, i.e., they should make a positive net economic value exchange. In Table 1 we present the semantics for the core elements of economic sustainability.

Example: Baggage handler, security provider, airport and airline are all legal entities that are profit-and-loss responsible. To be economically sustainable, it is essential that each of these actors makes profit and the whole ecosystem creates a positive cash flow.

Environment	The context where the *partners or competitors* work together to create a service. The environment possesses various *economic value objects* (investments, services and goods of economic value)
Actor	*Legal entities* that are profit-and-loss responsible, i.e., they are able to be profitable after a reasonable period of time (in case of an enterprise), or to increase value for itself (in case of an individual). Examples are enterprises such as 'airport', 'airlines', or individuals such as 'travelers'.
Value Object	Something of economic value that satisfies a particular need, or is used to produce other value objects. Examples are 'baggage transformation service' or 'money' which are both of value for traveler and airport.
Value Exchange	What an actor offers to (an outgoing offering) or requests from (an ingoing offering). For example, 'money' is transferred from the 'traveler' to the 'airline company', in return to `transferred baggage'
Factor	Something that determines the economic value of the value object in terms of monetary units. According to [10] of such factors include the valuation of: ● *What the service offers*, e.g. the capability that allows the customer to reach certain goals. For example, baggage handling is valued because it can help the customer to pay his/her bills ● *The perceived quality of the service* (secure vs. non-secure payment) ● *Beauty of the service* (travelers may appreciate the design of a the track-and-trace user interface, apart from its function and quality) .

Table 1: Core aspects of Economical Sustainability

4.2.2. Technical Sustainability

Technical Sustainability is the ability of a software service network to **cope with change and evolution**, while providing the requested features and capabilities. In the technical dimension, the *actors* are not only legal entities and individuals, but also systems that are either providers or consumers of a software service. This creates a *software ecosystem [11]* that represents the *environment* for technical sustainability. In this context, a *value exchange* is represented by the combination of requesting and providing a service, in terms of granting an actor the requested feature/capability that represents the *value object* for the service. Thus, the *value* of a feature is represented by its degree of fulfilling a specific need, hence a *fitness* (as an example see [12]). Of course, the fitness is determined by a number of *factors:* two obvious factors are the *customer needs* [10] of the actors, and the level of *quality* with which each service is offered to the consumer. In Table 2 we present the semantics for the core aspects of technical sustainability.

Example: Consider the baggage-screening service provided by the security provider to the airport. To be technically sustainable, this service should be able adapt to changes (e.g., changes in screening technology), while fulfilling the airport needs.

Environment	The context is a software ecosystem (system of systems) composed of prosumers that provide/consume services according to their needs and with some degree of quality.
Actor	Individuals, enterprises, systems that either provide or consume an IT service.
Value Object	The technical implementation of a feature/capability via an IT service. The technical value of functionality is its ability to fulfill a need. This ability can be measured in terms of fitness to a specific (goal/requirement/need).
Value Exchange	The combination of the request and provision of a service. A positive value exchange happens when the provided service not only fulfils the current need of the consumer, but also anticipates its implicit and/or future potential needs (e.g., additional features/capabilities, higher quality than what required)
Factor	The factors are what determine the fitness between a need and a provision of a service. These factors include: • Need: an actor needs certain functionality. • Service Quality: The functionality is provided with some quality of service.

Table 2: Core aspects of Technical Sustainability

4.2.3. Environmental Sustainability

Environmental sustainability revolves around the concept of natural resources and how e-Services make use of them. Due to the pervasive nature of ICT technologies and the worldwide scale at which they operate, e-Services are more and more interacting with the *natural ecosystem* of our planet. The ecosystem represents the *environment* in the environmental perspective of our conceptual model. This interaction translates into a *service network* composed by e-Services and *ecosystem services* [13], i.e. the benefits people obtain from ecosystems. In particular, for the purpose of this work we focus on *provisioning* services, i.e. goods and resources provided by our ecosystem such as food, water, energy, and *regulating* services, i.e. benefits obtained from the regulation of ecosystem processes such as waste treatment and climate. Those represent our *value objects* for environmental sustainability.

Example: The carts used by the baggage handling company consume fuel for each trip. Fuel is a form of energy provided by the ecosystem, hence it is a value object for environmental sustainability.

The *value* assessment of natural resources has been extensively investigated by researchers in economics and environmental sciences [14]–[16] and it is a controversial issue. Indeed, valuation is a necessary process if we aim at balancing between the different sustainability dimensions [17]. To represent environmental value, we use the concept of *natural capital [16]*, defined as “the stock of capital derived from natural resources such as biological diversity and ecosystems, in addition to geological resources such as fossil fuels and mineral deposits”. Hence, the service network is *sustainable* if the global natural capital of the value network is preserved, hence all value exchanges should have a *positive* net value. In Table 3 we present the semantics for the core aspects of environmental sustainability.

Environment	The Natural Ecosystem, i.e. "a dynamic complex of plant, animal, and microorganism communities and the nonliving environment, interacting as a functional unit." [13] Humans are an integral part of ecosystems.
Actor	Entities that make use of ecosystem services. For example, the Baggage Handling company uses an energy provisioning service to power the carts. The Airport company uses regulating services to regulate temperature and climate inside the airport.
Value Object	Objects that hold natural capital and environmental value. e.g. Fuel.
Value Exchange	A consumption or usage of ecosystem services from the environment, e.g. Fuel Consumption.
Factors	Factors are drivers of change in ecosystems and ecosystem services that alter the environmental value or the natural capital of a value exchange. For example, Climate change affects the weather conditions, hence the weather regulation services. Technological factors such as bio-fuels or solar-powered carts affect the energy provisioning services.

Table 3: Core aspects of Environmental Sustainability

4.2.4. Social Sustainability

Social sustainability entails the resilience by which e-Services uphold the fair exchange of information and social status among the actors involved in service exchanges. Actors in this case are considered as the people or organizations that assume a relevant role for the purpose of the service exchange. For example, a service owner is an *actor* during a service exchange. Also, *service providers and consumers are actors* during the exchange required for contractual agreements to take place. Social sustainability in this case is assured only if both parties can be guaranteed a fair and reciprocal information exchange.

Similarly, *their information exchange* during contractual agreements is considered *a value exchange*, since the contract itself can be seen as the social *value object* by which a social and organizational relation is established and maintained (based on trust and contractual restriction). The scenario in which the said information exchange takes place, is defined as the social *environment* of the information exchange. For example, a platform for e-Service sharing takes place to be a social environment through which the information exchanges above can take place. Said social environment should allow equal opportunities for organization, collaboration and profit to all actors involved in the information exchange in order to be sustainable.

Finally, the environment, actors, value objects and value exchanges can be influenced by a number of *social (or organizational) factors*. Said factors are contingencies dictated by any of the above elements and assume a fundamental role to regulate value exchanges and their fairness. For example, using an electronic platform for e-Service sharing offers constraints on the value exchanges possible since no direct way for informal face-to-face interaction is possible, in general. Factors are contingencies constraining the resilience of a social value exchange and, therefore, must be accounted and measured as mediators for social sustainability, in order not to incur in social debt regarding the e-service solution [18].

Example: travelers through an airport must trust on the reputation of airline companies for their baggage's location, safety and security. Airline reputation as well as traveler rights, as established by governmental rules and regulations, represent social value objects.

Environment	The organizational and social structure underlying service exchanges, that is, the set of organizations and social entities involved in service exchanges, together with the social (e.g., mutual trust) and organizational (e.g., contractual) relations that bind them [19]. For example, the baggage handling company, the airport management corporation, the human operator subcontractors, the security subcontractors are all part of the organizational-social structure involved in the baggage handling e-service, so are the social and socio-technical services part of such a structure.
Actor	Humans or organizations that play a role during service exchanges. For example, the Baggage Handling company uses security subcontractors for the safety and security of baggage. The airport uses monitoring and inquiry services to make sure that security is applied to all baggage and, also, that security personnel may only interact with said baggage in a purposefully governed way.
Value Object	Objects that hold social capital value or may yield social debt, e.g. trust and reputation among actors involved in a service network.
Value Exchange	A fair and reciprocal consumption, usage or exchange/agreement between social value objects, e.g. Security Scans from security personnel to baggage handling subcontractors involves an exchange of trust and validation which are both value objects in the overall organizational and social structure for the airport management organization.
Factors	Factors are social and organizational characteristics that determine the value exchange. For example, reputation affects the degree of trust that actors share in a value exchange. Other examples may be openness, laws, norms, beliefs and organizational culture.

Table 4: Core aspects of Social Sustainability

5. Discussion

Even with our simple running example, our conceptual model highlights various insights on how to assess sustainability aspects of a service network. First, by reducing sustainability assessment into a value modeling problem the conceptual model facilitates making comparisons and trade-offs. For instance, a service could be profitable from an economic perspective (hence economically sustainable) for its provider, but it might consume too many resources from the environment, hence in the long run it won’t be able to operate anymore. While, in [20] we enlist a number of trade-offs between economic- and technical dimensions, further research is needed to identify trade-offs across all the four dimensions.

Second, by focusing on valuation of sustainability in all 4 dimensions our approach takes a step towards assessment of sustainability, although quantitative valuation methods for each sustainability dimension are still needed.

A current limit of our approach is that, for the sake of simplicity, we do not consider the dynamic evolution of the service network: we currently evaluate “snapshots” of the network. Future work will address the development of *dynamic views* on sustainability, to show the evolution over time and on the different dimensions. These dynamic views will model how factors change over time, and consequently the value assigned to the value object varies. These views will support stakeholders in constantly monitoring the sustainability of their services and react to changes in the environment.

6. Conclusions

Sustainability of e-services must be approached from all four dimensions (economic, technical, environmental and social) In this contribution, we addressed 4D-sustainability as a value modeling problem. Our approach offers a number of interrelated core elements (common among the four sustainability dimensions) as well as dimension-specific elements, variable elements. Our approach uniquely addresses the multi-dimensional aspect of sustainability as a first class element. Also, by focusing on 4D core elements, we enable describing the essence of sustainable e-services in a unified manner. By focusing on variable elements we provide means to identify conflicts or trade-offs between dimensions. We also showed how to apply the conceptual model using a real-life case study featuring an airport baggage handling system. Our future research efforts will use this model as a basis to create a modeling notation and technique for 4D-sustainability of e-Services.

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